# Basic astrophysics and spacetime for beginners volume 2

### Recap

In the last volume in this series, we discussed about what spacetime is and why gravity is not a force. We also discussed what is a perspective in physics, and what observers are. If you have not read volume 1, please do read it and come back as we will build upon the concepts explained in that volume.

### Introduction to new concepts in physics

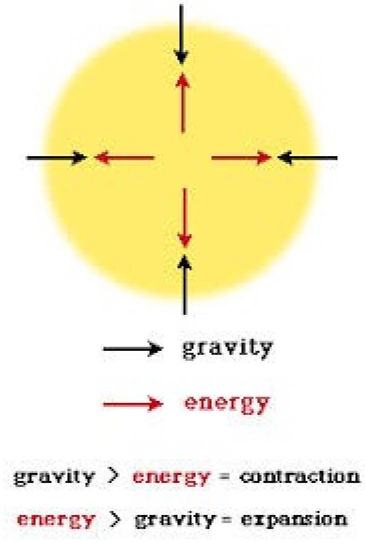
Today, we will learn about black holes, wormholes and white holes along with some additional information like past and future cones.

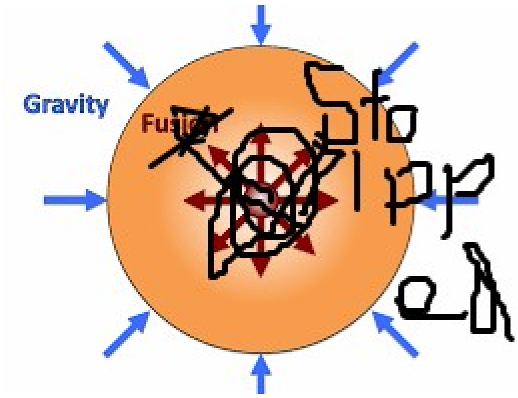
### Black holes

First, we will understand how black holes are formed and what exactly are they?

To understand how black holes are made, first let us understand what they are. Black holes are extremely dense collections of matter. They are formed when a lot of matter densifies (makes/becomes matter denser) into a black hole. This requires so much force and energy to densify the matter that black holes are almost always made when a star comes to the end of its life and goes supernova. A supernova is the event that a star 8 times the mass of our sun (eight solar masses) goes through when its life comes to an end. The star effectively dies when there is not enough fuel to produce as much energy as required to balance the force of gravity constantly trying to make it collapse, and it loses the support of outward pushing force of constant nuclear fusion reactions. When this happens, the gravity induced by the mass of the star is not balanced by any force, causing the star to collapse in on itself, causing a supernova.

Here is a diagram (on the next page)


gravity
energy
gravity > energy = contraction
energy > gravity = expansion


Gravity
~~Fusion~~
Stopped

End of life

Hence, when a supernova occurs, it densifies the matter that made up the star and hence leads to the creation of a black hole.

Now, let us understand what defines a black hole, and makes it a black hole

## The defining characteristics of a black hole

A black hole is differentiated from other bodies as it has unique characteristics, some of them are given here.

A black hole, once formed curves spacetime infinitely, and hence rips it. As it curves spacetime infinitely, space starts to flow towards it faster than the speed of light past the event horizon; the point of no return, meaning that if an object were to escape a black hole after crossing the event horizon (the point of no return), it would need to go faster than the speed of light, which, by special relativity, is impossible.

Also, as space is flowing faster, time stops moving and space starts moving. They both effectively switch roles. Let us understand why this happens

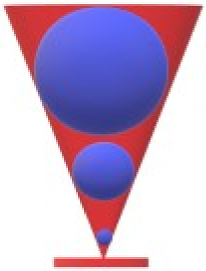
## Why space and time switch roles inside the event horizon

As previously discussed, space starts flowing faster the speed of light within the event horizon. Now, think of a situation where two glasses are present, and have a limited amount of water in both of them. Imagine the water to be the maximum speed that you can go at at a time. You cannot go faster than that speed (the speed of light) and both glasses share the same amount of water, and that water has to be poured from one glass to the other. The water is your movement in space/time and it’s limit to the speed of your movement is the speed of light. Now imagine the two glasses are space and time, when you are not moving, all of your movement is in time, so all of the water is in the time glass, when you move, you are also moving through the space dimension, so, some of that water is transferred to the space glass, now, when space is moving faster the speed of light, it is at the maximum speed possible, and all of the water is in the space glass, and hence, time cannot move and is frozen.

Also, here is an image of a black hole on spacetime

## 4-D past and future cones

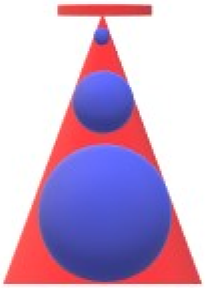
Imagine there is a person who is moving through time and has a helmet that sends out a sphere of light outwards in all directions, as he is moving through time, the light spreads out to form a cone in his future. Here is a diagram



This is his future cone, everything he will ever do is contained in this cone, since the sphere of light moves at the speed of light, so, to escape this cone, he would have to go faster than light, which is impossible.

Like this, if the was a big sphere of light collapsing back on itself, then everything he would have done in the past would have happened in that cone due to the same reason that he cannot go faster than light.

Here is a diagram



Now that we understand what are past and future 4-D cones, we will make use of them to also see why we cannot exit a black hole’s event horizon.

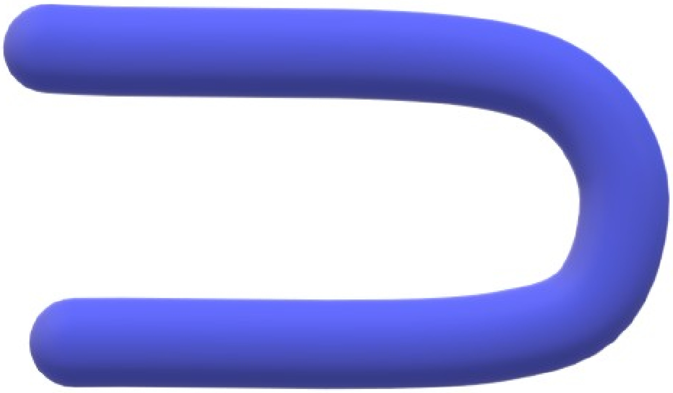
Imagine an object crossed the event horizon, then, as space is flowing faster than the speed of light, hence, even light cannot escape. If light cannot escape, then there would be only one light cone, one whose future cone pointed only towards the black hole’s singularity. This would mean that escaping the black hole is impossible.

## Singularities

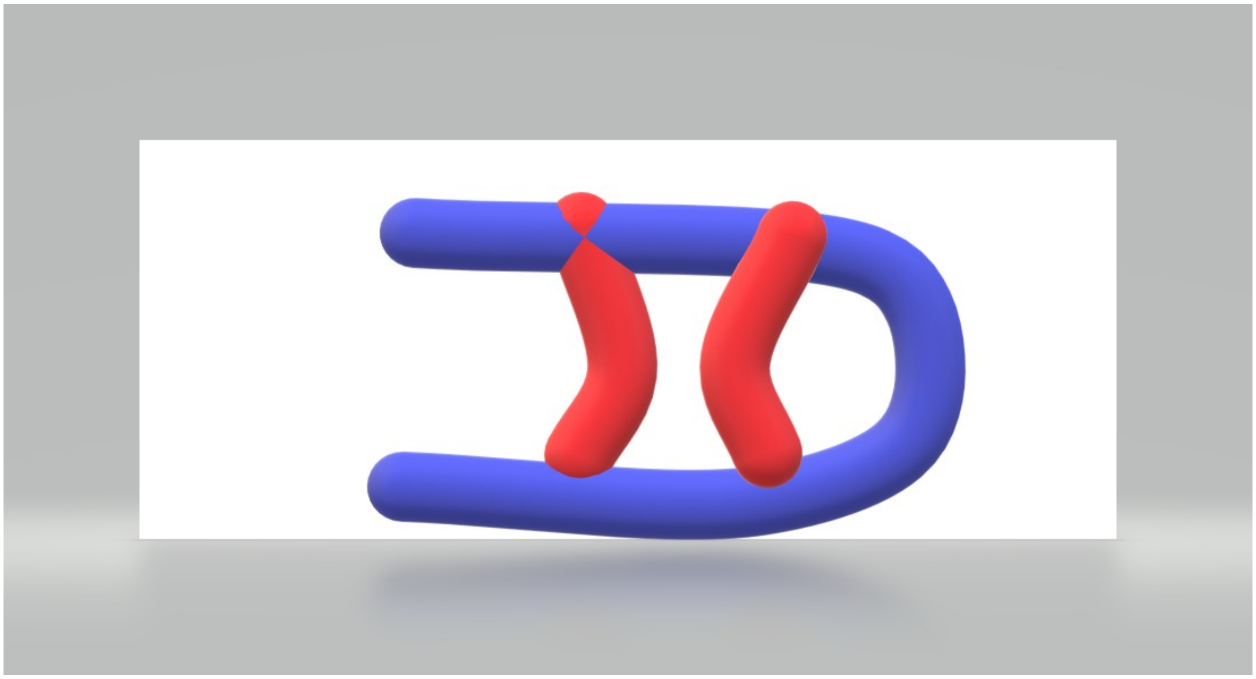
A singularity is the point in a black hole where there is an infinite amount of gravity, and infinite density. They are hidden by the event horizon. If they were exposed, then, you can get as close as you want to a singularity and nothing would happen, only if you hit it, you would die (horribly), and, all of physics would not hold. A singularity is in space, but, as space and time are reversed in a black hole, a singularity is actually in the future of an object and can only actually be experienced

## Worm holes

A wormhole is a connection formed in spacetime that connects two different physical pints in spacetime. A theoretical explanation as to how they CAN form is given here. Imagine that in a location, spacetime bends over on itself like this



Now, if there is massive curvature in the upper region, it can cause that spacetime to be curved down so that the upper layer can form a sort of “tunnel” to the bottom layer here is a diagram



Now, if something were to enter this wormhole, it would be transported directly to the other side of the wormhole, at least theoretically. You see, wormholes are not stable in time. They are unstable and their dimensions keep on varying. A wormhole can also be formed between two COMPLETELY DIFFERENT UNIVERSES. There are also theories talking about how a wormhole could start at a black hole and end at a white hole. But, we will talk about that in following papers.

### White hole

A white hole is the theoretical mathematical opposite of a black hole, that is, instead of pulling mass in permanently, it instead throws out mass and space faster than the speed of light, it may also be connected to a black hole in another universe through a wormhole. As this is still a theoretical concept, we still do not know much about them, but, if they do exist, they would still look black because there would still not be as much light coming out of it.

# Thank you

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